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CFD for Tidal Resource Assessment

Abstract

Tides and, more recently, their power potential have attracted much scientific interest over many centuries. In 1776, Laplace proposed a dynamic long wave theory based on mass continuity and horizontal momentum principles. Laplace's tidal equations neglected convective accelerations, but included Coriolis acceleration terms related to the rotation of the Earth. In the 19th C and early 20th C, Kelvin, Lamb, Poincaré, Taylor and others developed analytical solutions for long waves affected by Coriolis acceleration and non-uniform bed topography. This presentation will briefly examine the history of tidal flow models, before considering ongoing developments in CFD for tides and tidal stream power assessment in coastal basins. The bulk of the hydrodynamic analysis will be based on the non-linear shallow water equations. Two methods will be described for including tidal devices in a coastal basin shallow flow model: enhanced roughness and linear momentum actuator disk theory. Both approaches involve abrupt changes to the flow hydrodynamics, and so an integral finite volume shock-capturing or discontinuous Galerkin scheme is necessary. Model verification will be described for a tidal fence in a strait. Case studies will be presented of tidal resource assessments of sites in the Pentland Firth, Scotland, and off the Anglesey Skerries, Wales. The presentation will also outline the derivation and direct solution of the shallow water-sediment equations comprising a fully coupled system of mass and momentum conservation laws and empirical formulae that extend the hydrodynamic analysis to include bed load sediment transport, suspended sediment transport, sediment deposition and entrainment, and bed morphological change. By careful selection of dependent variables, it is possible to solve the hyperbolic shallow water-sediment equations in conservative form. Illustrative simulations will be presented of a dam-break flow over an erodible bed. In addition to having a wide range of other applications (e.g. to flows in rivers containing cascades of dams), the equations provide a means of determining the environmental impact of tides and tidal energy devices. Turning to device-scale modelling, the presentation will consider the use of high performance CFD methods (including large eddy simulation) to model three-dimensional turbulent tidal flows and the swirling flow hydrodynamics in the vicinity of axial tidal turbines. The presentation will conclude with a discussion of the certain major issues remaining in tidal resource assessment, including model uncertainty, wave-current interaction, scale-up of three-dimensional swirling flows behind turbines to coastal-scale models, turbulence, and large-scale eddies.

Alistair Borthwick: Short Biography

Alistair Borthwick has more than 35 years' engineering experience, and was a member of the design team of the Hutton Tension Leg Platform, which won the Queen's Award for Technological Achievement in 1984. He is Head of Mechanical Engineering and Professor of Applied Hydrodynamics at The University of Edinburgh, and an Emeritus Fellow at St Edmund Hall, Oxford. Prof. Borthwick was previously a Professor of Engineering Science at the University of Oxford, where he worked for 21 years from 1990-2011. He was Head of Civil & Environmental Engineering at University College Cork from 2011-13, where he was the Founding Director of the SFI Centre for Marine Renewable Energy Ireland. His research interests include environmental fluid mechanics, computational hydraulics, flood risk management, and marine renewable energy. He was the founding Chairman of the Editorial Board of the *ICE Journal of Engineering and Computational Mechanics*. Prof. Borthwick was awarded a DSc by the University of Oxford in 2007. He is a Fellow of the Royal Academy of Engineering and a Fellow of the Royal Society of Edinburgh.